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SILLIMAN, HARE AND COOKE, AND THEIR RELATION TO AMERICAN SCIENCE.

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THE first two hundred years of American history is strikingly bare in the annals of science. Such a condition of affairs is not strange, when we consider the conditions that obtained. The early emigrants to this country were not, as a rule, from the class that produced scholars, and their existence here was a struggle for things material and political.

Two men only had demonstrated that the New World could produce men of the keenest scientific mind; and they were the "many-sided" Franklin, whose discoveries in electricity had brought him unsought membership in the Royal Society, and whose advice, pregnant with results, had encouraged Priestley in his classic researches; and Benjamin Thompson, Count Rumford, who, casting his lot with the mother country in the war of independence, did his scientific work in England and on the continent, but whose influence in the Rumford Foundation extends its material aid to American science to the present day.

As was natural, the early scientific efforts of this country were directed along the descriptive lines of botany, natural history, geology and mineralogy, and the names of Cutlar, Wistar, Mitchell, Hosack, Bartram and Trooste all deserve grateful remembrance for their labors.

Chemistry, the science whose course I wish to follow more especially, was, at the beginning of the nineteenth century, little more than a name in the new republic. The latter decades of the eighteenth century in the Old World had witnessed an unparalleled advance in chemical knowledge. When we recall the names of Black, Bergman, Scheele, Lavoisier, Priestley, Cavendish and Klaproth we realize that "there were giants in those days." The era of quantitative measurements, of a true theory of combustion and of exact analytical meth-

ods was destined to change a descriptive science into an exact science.

But the New World was soon to catch an echo of these discoveries, when Priestley, theologian, scientist and last defender of the "phlogiston" theory, driven from his English home by a mob, landed in New York in 1794. Proceeding to Philadelphia, he was greeted with an address from the American Philosophical Society, and by an unanimous vote of the trustees was offered the professorship of chemistry in the University of Philadelphia. This he refused, retiring instead to the little town of Northumberland, where he was engaged in literary and scientific work until his death, in 1804. To Priestley, to Woodhouse, professor of chemistry in the University of Philadelphia and pupil of Humphrey Davy, and to John McLean, professor of chemistry at Princeton, who had received his training under Black and Lavoisier, we owe in great part the increased interest in chemistry in America at the beginning of the nineteenth century.

That such an interest was awakened is shown by the passage of the following resolution, at the suggestion of the shrewd president of Yale, Doctor Dwight, September 12, 1798: "Voted, that a professorship of chemistry and natural history be instituted in this college as soon as the funds shall be sufficiently productive to support it." Four years later it was "Voted, that a professorship of chemistry and natural history be, and hereby is, instituted in this college. Voted, that it is expedient to select for a professor of chemistry and natural history some person of competent talents, giving him such time to give his answer, whether he will accept such appointment or not, as he may desire and as may be agreed upon between him and the corporation." For this position Benjamin Silliman, esq., was declared chosen. Silliman at this time was twenty-three years of age. He had graduated at Yale at the age of seventeen and had later returned to his alma mater as tutor. He accepted the appointment, with the proviso that time and opportunity be given him to become acquainted with his new duties. He had this advantage: he came to these unfamiliar fields with mind wholly free from prejudice. He had nothing whatever to unlearn. As he remarks: "During my novitiate chemistry was scarcely ever named. I well remember when I received my earliest impressions in relation to

chemistry. Prof. Josiah Meigs delivered lectures on natural philosophy from the pulpit of the college chapel. He was a gentleman of the greatest intelligence, and had read Chaptel, Lavoisier and other chemical writers of the French school. From these, and perhaps other sources, he occasionally introduced chemical facts and principles in common with those of natural philosophy. I heard from him that water contains a great amount of heat that does not make the water any hotter to the touch or to the thermometer; that this heat comes out of the water when it freezes, and still the freezing water is not warmed by the escaping heat. This appeared to me very surprising, and still more astonishing did it appear that water could not be made any hotter by urging the fire. My curiosity being aroused, I opened the encyclopedia, and there read that balloons were inflated by an inflammable gas obtained from water; and I looked with intense interest at the figures representing the apparatus by means of which steam, made to pass through an ignited gun barrel, came out inflammable gas at the other end of the tube. These and similar things created in my youthful mind a vivid curiosity to know more of the science to which they appertained."

Before he committed himself to the new science, Silliman passed his examination for admission to the bar, that he might have a respectable profession to fall back upon in case the chemical venture failed to succeed. The winter of 1802-'03 was spent in Philadelphia as a student with Dr. James Woodhouse. Woodhouse, who seems to have been a shrewd and observant man, had appeared as a defender of the French school in a paper opposing the phlogiston views of Priestley. He was also the first one to point out the superiority of anthracite over bituminous coal.

As a picture of the chemical instruction at this time, let me again quote Silliman: "The chemical lectures were important to me, who has as yet seen few chemical experiments. Those performed by Doctor Woodhouse were valuable, because every fact, with its proof, was an acquisition to me. The apparatus was humble, . . . and our instructor delighted, though he did not excel in the performance of experiments. He had no proper assistant, . . . and the work was imperfectly done. He had not the gift of a lucid mind, nor of high reasoning powers, nor of a fluent diction; still we could understand him. Doc-

tor Woodhouse was wanting in personal dignity, and was, out of lecture hours, sometimes jocose with the students. . . . In his person he was short, with a florid face. He was always dressed with care; generally he wore a blue broadcloth coat with metal buttons. His hair was powdered and his appearance was gentlemanly. His lectures were quite free from any moral bearing. At the commencement of the course he treated with levity and ridicule the idea that the visitations of the yellow fever might be visitations of God for the sins of the people. He imputed them to material agencies and physical causes. I should add, respecting his lectures, that they were brief. He generally occupied a third or a fourth of the hour in recapitulating the subject of the preceding lecture, and thus advanced at the rate of about forty or forty-five minutes in a day."

One of the most valuable experiences for Silliman during the two winters he passed in Philadelphia was his acquaintance with Hare. They worked much together with the oxyhydrogen blowpipe, which had been recently invented by the young Philadelphia chemist.

It was also the good fortune of Silliman to meet, at the table of Doctor Wistar, Joseph Priestley, and he speaks of him as follows: "In person he was small and slender. His age was then about seventy. His dress was clerical and perfectly plain. His manners were mild, modest and conciliatory; so that, although in controversy a sturdy combatant, he always won kind regard and favor in his personal intercourse. Speaking of his chemical discoveries, which were very numerous, Priestley said: 'When I had made a discovery I did not wait to perfect it by a more elaborate research, but at once threw it out in the world, that I might establish my claim before it was anticipated.' " This method was certainly characteristic of the older scientist and at times led him into error.

The second period in the education of Silliman was the winter of 1805-'06, which was spent in England. Part of this time was passed in London in the laboratory of Frederick Accum, where the days were devoted to the analysis of ores, to the preparation of crystallized vegetable acids, to the investigation of arsenic compounds, etc.; in short, a course in analytical and preparative chemistry, facilities for which had been lacking in Philadelphia.

In 1806 he migrated to Edinburgh, to attend the lectures of

Professor Gregory and Dr. Thomas Hope, the discoverer of strontium. I cannot forbear from giving another quotation, because it illustrates so well the ideals of chemical instruction at this time. "Doctor Hope's lectures were not only learned, posting up the history of discovery, and giving the facts clearly and fully, but the experiments were prepared on a liberal scale. They were apposite and beautiful, and so neatly and skillfully performed that rarely was even a drop spilled on the table. No experiment failed, except that in two instances glass vessels were broken by the heat evolved in the experiment —in one case by burning phosphorus and in another by sulphur and iron filings combining with incandescence when gently heated, but in these cases there was no fault of the experimenter; the experiment was hazardous to the vessels, and in such cases, if the lecturer states the fact beforehand, he will save his credit, even if the glass be shattered. Doctor Hope lectured in full dress, without any protection for his clothes; he held a white handkerchief in his hand and performed all his experiments upon a high table, himself standing on an elevated platform, and surrounded on all sides and behind by his pupils. His lectures were all written out but very rarely read. He was cool and lucid, but sometimes, rising above his manuscript, he essayed a flight of eloquence. In these cases he was not very successful." Hope was a pupil of Lavoisier and Black, whom he took for his model. Black is known to us by his classic research, "Experiments on Magnesia Alba," in the course of which carbon dioxide was rediscovered, and by his discovery of latent heat.

Besides chemistry, Silliman listened to lectures in Edinburgh on geology, mineralogy and medicine. He also during this year made the acquaintance of Dalton, Davy and Wollaston.

If time allowed it would be interesting to speak of the early handicaps of Silliman at Yale, of his subterranean laboratory, of his difficulties in procuring apparatus. For instance, he sent to a glass factory in Connecticut, as a model, a retort, the neck of which was broken from the bulb. In due time he received a carefully packed shipment of retorts, the necks and bulbs being placed side by side: all having been neatly cracked in order to duplicate the original retort.

For the next half century, Silliman spent a busy life as teacher, investigator, public lecturer, and from 1819 editor of the American Journal of Science, which he founded. Those

were years of enormous value to American science, not only for the men who were trained in the old laboratory at Yale—men like Dana (the great mineralogist) and Johnson (the pioneer in agricultural chemistry)—not only for the publication of the American Journal of Science, which "was for two-thirds of a century the most prominent register of the scientific work of the continent," but also for what these years meant in the education of part at least of the American people into an appreciation of the value of scientific work and investigation as it relates to the welfare of the state. Unless we consider the conditions in America seventy-five or one hundred years ago, we can hardly appreciate the services of Silliman, Hare, Griscom and others in their efforts toward popular scientific instruction. The educative value of it cannot be directly estimated, but its results were far-reaching, and to-day we are reaping its benefits.

Silliman was a man of broad interests and literary skill. His accounts of a journey to Canada, of his year in England in 1805-'06, and of his travels on the continent fifty years later, are still worth reading. One phase of his civic activity relates directly to our own state. He was instrumental in furnishing with rifles one of the New England colonies which made its way to Kansas, and later he signed a remonstrance which was forwarded to President Buchanan protesting against the use of the United States troops in enforcing the slave laws. For this stand he was bitterly assailed in the press and in the senate of the United States. In the latter body a defense and eulogy of Professor Silliman was pronounced by Senator Foster and Senator Dixon. In other fields also Silliman showed the wide range of his interests.

Robert Hare was born in Philadelphia in 1781, and in the same city spent the seventy-seven years of his long and fruitful life. His early training differed from that of Silliman and Cooke, in that it lacked the rigid classical drill they had both passed through. His predilection toward chemistry manifested itself at an early age and was fostered by his membership in the Philadelphia Chemical Society, where his associates and teachers were Priestley, Woodhouse and Seybert, the latter being a product of the School of Mines in Paris. From 1818 to 1847, Hare was professor in the University of Pennsylvania, where like Silliman he exercised a great influence as a teacher and exponent of scientific truth. He had, however, what Silli-

man largely lacked—originality; or, as we would now say, "research ability." While in the first fifty volumes of the American Journal of Science Silliman has only twenty-nine contributions of moderate importance, Hare's titles in the same volumes number some one hundred and fifty, in the fields of chemistry, physics and meteorology. The subjects range from descriptions of new apparatus, processes for making fulminating powder, analysis of gaseous mixtures, methods of detecting minute quantities of opium, to contributions on the theory of atoms, the nature of acids and bases, and the principles of chemical nomenclature. Space forbids any extended description of these papers, but two of them deserve at least a passing notice. Hare when a youth of twenty invented the oxyhydrogen blowpipe, a discovery which was later rewarded with the first Rumford medal. Lavoisier had obtained high temperatures by directing a stream of oxygen on glowing charcoal, but it was left for Hare to show that the maximum possible effects of heat could be obtained by surrounding the body to be heated with an atmosphere of burning gas, produced by burning hydrogen in an atmosphere of oxygen. In the hands of Hare and Silliman this apparatus, until the invention of the electric furnace, was the most powerful means for the development of high temperatures. By its aid metals like gold and platinum were not only fused but vaporized, while silicates, the precious stones, the oxides of barium, strontium and calcium were fused. Growing out of it are the later technical uses, the Drummond or calcium light and the purification of refractory metals like platinum.

Silliman, in an article in the Journal of Science, describes some experiments where plumbago or natural graphite was subjected to the heat of this flame. He speaks of obtaining crystals that would scratch glass, results which would indicate that he had obtained the silicide of carbon or carborundum, a product now manufactured in the electric furnace and one of great importance as an abrasive agent. A second interesting discovery of Hare was the "calorimeter," a description of which was published in 1819 in a memoir entitled "A New Theory of Galvanism." The apparatus consisted of large plates of copper and zinc which could be plunged into dilute acid. This was modified in 1820, in that sheets of copper and zinc containing several hundred square feet, separated by felt, saturated with acidulated water, were made into

a roll. Enormous heat effects were obtained by this current, so much so that Silliman in 1823 was enabled to demonstrate the fusion and volatilization of carbon, a result of great interest. Using a battery of this type, Hare in 1831 made the first application of electricity to blasting under water.

We must not be too critical in our judgment of these papers of Silliman, Hare and their associates. From the standpoint of pure synthetic research they doubtless will be found wanting, but they had their place, and a most important one, in the development of scientific knowledge and spirit in America.

The third member of this illustrious trio, Josiah Parsons Cooke, began his work in the '50's, just at the close of the active labors of Silliman and Hare. As Philadelphia and New Haven had each made its contribution to science, so now it was the turn of Cambridge to carry on the torch of progress. Professor Cooke's interest in chemistry received its stimulus from the public lectures of Silliman, delivered on the Lowell Foundation. These were listened to with great eagerness, and the young lad supplemented these lectures by working through all the experiments in Turner's bulky volume in a small laboratory fitted up in his own home. His undergraduate days, which ended in 1848, offered him no opportunity to increase his store of chemical knowledge, because the only instructions given in that subject were a few desultory lectures of Professor Webster, of lamented fame.

In the fall of 1849 he was appointed tutor in mathematics, being transferred the same year to an instructorship in chemistry, thus giving him the eagerly desired opportunity. The next fall, at the age of twenty-three, he was made Eirving professor of chemistry and mineralogy. The other candidate for the position was David A. Wells, later the great political economist, the first graduate in chemistry of the Lawrence Scientific School. Why the untrained man was chosen in place of Wells we do not know, but for once the choice was a most fortunate one. The secret of the success of this young man was his ability, his store of common sense, and an insistent persistency which overcame in time all obstacles.

Cooke was essentially a self-taught man. He had, it is true, heard a few lectures from Regnault and Dumas in Paris, but only for a short time. He was, however, characterized by his ability to "keep abreast of the times" and to recognize the important fields of chemistry as they developed and to add

them to the Harvard curriculum. To him came the necessity of shaping and developing the entire instruction in chemistry, and how well he succeeded the history of that department shows. A member of his first class, and later assistant in the department, was Doctor Eliot; and I have no doubt that the influence and efforts of Professor Cooke had much to do in molding the ideas and assisting the labors of President Eliot in the development of Harvard from college to a great American university.

Professor Cooke's contributions to Harvard and to American science are his services as a teacher, as an investigator, and as an exponent of scientific culture.

The first duty of a professor at that time, as it is now, in the American college is toward the actual instruction in his department, and from this standpoint Cooke accomplished much in bettering the methods and aims of scientific teaching. He developed in the college the laboratory method of teaching physical science. Silliman and Hare had followed a system of rather florid lectures, profusely illustrated with interesting experiments, but so far as actual manipulation was concerned the student remained a receptive, possibly, but passive, agent. Cooke sought to develop in the student by these laboratory methods the power of close and accurate observation and the ability to reason clearly from these observations, an aim which is the concrete essence of the value of all science training. Again, he sought to make chemistry not only a descriptive but an exact and disciplinary study. In this connection it is interesting to note that Professor Cooke published, in 1855, a little book on chemical equations and problems, as a drill for his class in the exact quantitative relations in chemistry. This is the first book of the kind with which I am acquainted, and it shows his desire to promote the rigid accuracy which forms the basis of any adequate science teaching.

To most of us only one gift is granted—that of adding by dint of much labor some new fact to the ever-increasing store of knowledge, but to some few there is given a clearer vision, which enables them to assort these scattered facts and derive from them a general law. To a certain degree this latter faculty was granted to Cooke. In 1854 he published a paper on "The Relation Between the Atomic Weights." Here he arranged the elements in a homologous series, which was to show the relation between them as does such a series in organic

chemistry; and while he failed in anticipating the work of Newlands, of Mendelleef and of Lothar Meyer, he did catch a glimpse of the great truth "that we must not merely separate out here and there the so-called related elements, but must grasp the fact that there is a relationship even between the apparently dissimilar." This ability to grasp a subject is seen in his books, "The New Chemistry" and "Chemical Physics," which were remarkably clear and adequate presentations of the fundamental conceptions of chemistry. Of Professor Cooke's investigations, time permits us only to recall the determination in 1877 of the atomic weights of antimony, and ten years later, with T. W. Richards, the work on "The Relative Values of the Atomic Weights of Oxygen and Hydrogen."

These papers from the Harvard laboratory were the inspiration of that most brilliant series of researches by Richards and his pupils, which are marvels of careful and painstaking work, so that the efforts of these men, coupled with the classic memoir of Morley on "The Relation between Hydrogen and Oxygen," and the labors of W. A. Noyes, have given to American science the foremost place in this phase of scientific investigation.

Lastly, Professor Cooke stood as one of the best exponents of "scientific culture." His address on that subject, written in 1875 and published in the Popular Science Monthly, deserves to be read and reread by every follower of science. His breadth of view is well illustrated by the following sentence from the address, which was delivered at the opening of the summer school at Harvard: "Moreover, I hope, my friends, that you will come to value scientific studies, not simply because they cultivate the perceptive and reasoning faculties, but also because they fill the mind with lofty ideals, elevated conceptions and noble thoughts. Indeed, I claim that there is no better school in which to train the esthetic faculties of the mind, the tastes and the imagination than the study of natural science."

These men then are the three great names among the American chemists of the nineteenth century, and they are surpassed by none for their services in promoting scientific methods, ideas and ideals. The value of the past is largely in the light it gives to the present, and it seems to me that there are two lessons which can be drawn from even this brief account of their life activities.

The first is that they stood for rigid accuracy in observation and thinking. In an experience of almost two decades of

teaching, my observation is—and I think that those of you who are teachers and those who have observed the results of secondary and college instruction will bear me out—that there is an almost universal lack of accuracy in thinking and working among our young people. The fault lies in no one place, but permeates the whole general scheme of education. Nor is it anything new. The malady was observed long ago, and the introduction of science teaching into our schools, which it was hoped would prove an antidote to the disease, has not alleviated the situation.

Some of the causes are not especially far to seek. Too much importance is placed on mere memory. As Professor Cooke remarks, "Many a student will solve an involved problem in algebra readily enough, so long as they can do it turning their mental crank, when they break down on the simplest practical problem of arithmetic, which requires of them only thought enough to decide whether they shall multiply or divide." To the average college student, "the acquisition of the elementary principles of a science is burdensome and distasteful," simply because, if the course is given rightly, he is forced to use methods of thought, in which he is wholly untrained; and it is difficult in the second place because he usually has no comprehension of the need of accuracy.

One of the causes of this latter failing is the introduction of the multiplicity of subjects into the secondary schools. The American plan has been to put every kind of a literary dish on the table, from nature study to psychology, and hand out a portion of each to the unfortunate pupil; and I fear, too, that much of the menu could not be guaranteed under any literary "food and drug act." The result is severe mental dyspepsia. The mental and moral make-up would have been much better nourished with a few subjects, chosen according to their needs, well "Fletcherized" and thoroughly digested. The fault goes back to the whole spirit of the American people—a spirit that likes to deal with large numbers and in glittering generalities—and in this regard a time has come when there must be a change. Our whole system of life, our agriculture, our economic processes, must be not alone extensive but intensive.

The second characteristic of these men that we should emulate is their broad interest in the various phases of human activities and knowledge. This is a point that I wish to emphasize especially. It seems to me that the ideal result of the

study of science is to arouse an intense intellectual curiosity in the many sides of human activity. The lack of such an interest is, I find, another of the common faults of our young people. The printed page means nothing but a printed page; something to be gotten through with and out of the way. The wider aspects of the subjects are meaningless. This ought not so to be. Take, for instance, the fields of natural history, geology, chemistry and physics; when you consider them from the scientific, economic, historical and human side, there is little of life they do not touch and illustrate.

That a thorough sicentific training does develop men of the broadest sympathies is seen in the call to the headship of some of our leading universities of the chemists Eliot, Remsen, Venable and Avery, of the physicists Nichols and MacLaurin, the geologist Van Hise and the zoölogist Jordan. The ideal result of this training is to make men "who think that nothing of humanity is alien to themselves."